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# BROKEN BOTTLES AND QUARTZ-SAND: GLASS PRODUCTION IN YORKSHIRE AND THE NORTH IN THE ROMAN PERIOD

JENNIFER PRICE

Although glass working took place in virtually every area of the Roman world, the evidence for glass production is generally rather difficult to identify and interpret. There is a marked contrast between the wide range of vessels and objects, which survive complete in burials or, more frequently, are found in fragments on settlements, and the ephemeral and episodic nature of the evidence for the production processes by which they were formed. In part, this can be explained by the processes themselves, as most Roman glass vessel and object production probably took place in association with very small furnaces, and the various categories of waste glass created by the production processes were normally recycled, leaving little diagnostic material to be identified.

Several categories of evidence for glass production in the Roman period have been recorded in military, rural and urban settlements in Yorkshire and northern Britain, and this evidence forms part of the wider picture of production in the province of Britain and other north-western provinces. This paper will present a brief précis of the evidence for the nature of glass production in the Roman world as the background for this regional study; it will then examine and evaluate the strands of evidence identified in Yorkshire and northern Britain against this background; and will conclude with a consideration of the reasons why so much of the evidence is invisible or difficult to interpret.

## Evidence for Roman glass production in the Roman world

Archaeology is always the principal source of information for investigations into Roman glass production, as it is for other craft processes at this period. The archaeological evidence is sometimes augmented by information from literary works,<sup>1</sup> or epigraphic records,<sup>2</sup> or iconography,<sup>3</sup> but these provide only very limited detail. In particular, the literary surviving accounts have a strong bias towards the Mediterranean provinces.

It is now accepted that much of the production was divided into two distinct groups of activities which could, but did not have to, take place in the same localities. These were *primary production*, in which glass was made from the basic raw materials, using sand as the former, lime as the stabiliser and soda as the flux; and *secondary production*, in which glass already made was reheated and worked to produce glass vessels and objects.

### Primary production

Although the direct evidence for primary production is very limited, it seems that this was generally a specialised

pyrotechnical process, requiring access to supplies of suitable raw materials, good stocks of fuel, and a furnace capable of sustaining high temperatures for the duration of the melting process. Of the raw materials, the sand and lime were very widely available.<sup>4</sup> Soda, however, was more difficult to obtain. Deposits of mineral soda (natron) were rare in the Roman world, the greatest concentration being in Egypt, in the Wadi Natrun and elsewhere. Literary references indicate that natron was traded during the early empire around the coasts of the east Mediterranean, perhaps to India, and to southern Italy,<sup>5</sup> but it is uncertain whether this material, which was both soluble in water and corrosive, was regularly an empire-wide item of trade.

Few primary production sites have been identified, and most have been found in the same regions of the East Mediterranean, Syria-Palestine and Egypt (Figure 1), as the raw materials mentioned above. It is, however, noteworthy that where these sites can be dated they belong to the sixth-seventh and later centuries, and that no examples dating from the first-fifth centuries have yet been noted (*cf.* the discussion of lumps of glass, below).

Several primary production sites have been recorded in Israel. These sites, with rectangular furnaces estimated to be producing up to eight or nine tons of glass at each firing, were engaged in glass manufacture on a large scale. At Bet Eliezer, close to the Mediterranean coast near *Caesarea Maritima*, a complex of seventeen rectangular furnaces built in mud-brick, each measuring approximately 4 x 2 metres internally was excavated in 1992 (Gorin-Rosen 1995; Freestone and Gorin-Rosen 1999, 105-06, fig 3). The furnaces were aligned south-west to north-east, presumably to use the prevailing wind, with a double flue at the south-west end. The structure of the furnaces indicates that the glass in them was made from the raw materials as a one-stage process, without a preliminary fritting phase.<sup>6</sup> The slabs of glass were then broken up and moved away, leaving only small pieces. Similar furnaces have been recorded at Dor and *Apollonia*, which are also close to the Mediterranean coast (Freestone and Gorin-Rosen 1999, 108), and a large rectangular glass slab which failed to melt completely, measuring 3.4 x 1.95 x 0.45 metres and estimated to weigh about nine tons, is known from Bet She'arim in lower Galilee. However, it has been argued that this episode of primary production may be Islamic rather than Roman or Byzantine, perhaps dating from the early ninth century (Freestone and Gorin-Rosen 1999). Evidence of large-scale primary glassmaking has also been recorded in Egypt, at *Taposiris Magna*, south west of Alexandria, and at several

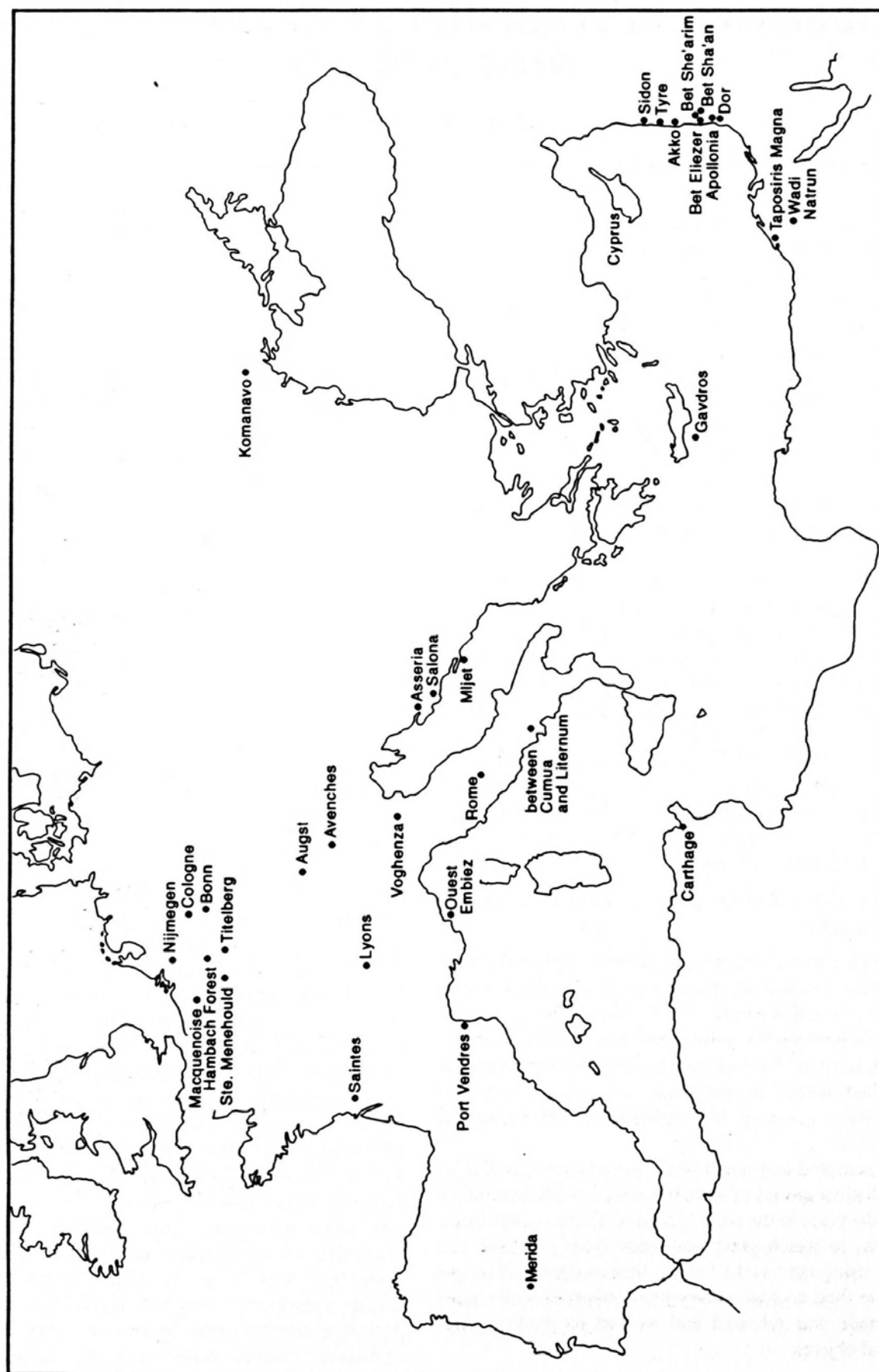


Figure 1. Map: sites outside Britain mentioned in the text



sites in Wadi Natrun, north west of Cairo (Saleh et al 1972; Nenna et al 1997). The sites have been identified by field survey which have found glass blocks, fragments of tank furnaces and other debris, but furnace installations have not yet been noted and the sites are not closely dated within the Roman period.

After the slabs of glass had been broken up they were presumably moved away, either by land or by sea. The positions of most of the primary production installations described above would have been very convenient for loading the lumps of glass onto ships, as they are situated close to the Mediterranean coast. The sea-borne transport of lumps of glass within the Mediterranean region is attested from chance finds and shipwrecks. A lump of blue-green glass from a wreck was found in the sea to the north of Gavdos, an island off the south west coast of Crete (Weinberg 1963, 107), and similar finds have been noted off the coast of Israel (Gusta Jacobson *pers comm*). These finds are undated, but shipwrecks with lumps of glass as part of the cargo indicate that this practice occurred in the Roman world. A wreck dating from the later first century AD found close to the island of Mljet, Croatia, contained about 100kg of blue-green lumps (Radic and Jurisic 1993, 122, fig 7.2), and wrecks dated to the early third and early fifth century are known off the coast of southern France, such as Ovest Embiez 1 which contained colourless lumps, and Port Vendres 1, which contained yellowish green lumps (Foy 1997). The glass lumps may have been carried in the ships as a form of ballast, like lead ingots or building stone, as well as being cargo to be traded at various ports.

### Secondary production

Much more is known about sites concerned with secondary production. Glassworking sites have been found throughout the Roman world, and they provide most of the archaeological evidence relating to the production of vessels and objects (Figure 1). These sites may produce the remains of furnaces or annealing ovens, or crucibles, or tools and other equipment. Glass production sites are also identified by the presence of certain characteristic categories of waste glass, such as the surplus pieces of glass and drips and trails remaining from the production processes; broken vessels or objects produced at the site; deposits of broken vessel glass collected from the production site or brought from elsewhere for re-cycling; and blocks of glass from the crucibles and lumps of raw glass.

**Furnaces** The furnaces and installations such as annealing ovens are the features most likely to be recognised, though little more than the ground plans usually survive. These structures are generally very small. For example, the furnaces in the first-century glassworking site at Avenches (*Aventicum*), Switzerland had internal diameters of 0.50-0.65 metre (Morel et al 1992, 5-6, figs 3-7), and circular and rectangular glassworking structures at Eigelstein, in Köln, Germany, were nearly all less than 1.0 metre in internal dimensions (Follman-Schulz 1991).

Finds of the clay superstructures are very fragmentary and much of the current information about the appearance of the furnaces derives from contemporary representations on two

pottery lamps and an Egyptian terracotta group.<sup>7</sup> The pottery lamps, which date from the later first century AD were found at Asseria in Dalmatia (Abramic 1959) and at Voghenza, Ferrara, in north-east Italy (Baldoni 1987); they show the same glassworking scene which includes a low, domed furnace structure with two apertures, indicating two levels within the furnace (Figure 2), while the terracotta group (Price 1988a), dated to the first or second century AD, shows a tall conical structure, also with two apertures (Figure 3). The tall cone presumably served as a chimney to assist in raising and maintaining the temperature to heat the glass.

Neither of these scenes illustrates the arrangements for annealing<sup>8</sup> which was an essential process in the production of blown glass. Depictions of medieval glass furnaces show that an annealing chamber was sometimes sited in the third level within the furnace (for examples, see Charleston 1978, 11, 13, figs 1-3; Foy and Sennequier 1989, 111 no 48, 113 no 49a-b pls 1, 4 and fig), or attached to the side of the furnace furthest away from the flue (Charleston 1978, 22, fig 16), but evidence for similar arrangements in Roman furnaces survives very rarely. It is possible that separate structures for annealing may have existed at glass production sites, but little is known about these. Alternatively, a quite different arrangement which did not involve any kind of structure, such as a pit filled with ash and/or sand may have been used for the controlled cooling of the vessels.<sup>9</sup>

**Crucibles** The archaeological and iconographic evidence for the size of the furnaces described above indicates that they would generally have held only one container for the glass at a time. Whenever containers have been found, they are made of fired clay, and two kinds have been recognised, pots with circular mouths and convex or straight sides, and rectangular, trough-shaped containers, often known as tanks.

The first appear to have been open bowls. An object of this



Figure 2. Glassworking furnace, lamp from Asseria (after Abramic 1959)

kind is held in the right hand of the winged figure standing before the furnace structure on the terracotta group (Figure 3), and archaeological finds indicate that these containers were usually of ordinary earthenware pottery of kinds also used in contemporary domestic and funerary contexts. The examples in the workshop in Avenches were forms well-known in other contexts in the city (Heidi Amrein *pers comm*), as were those from the late second - early third-century workshops at Augst (Rütti 1991, 151-53, figs 96-98, pl 218.07), while the examples from the late Roman workshop at Titelberg in Luxembourg (Sternini 1995, 77, fig 90; van Geesbergen 1999, 112-13, fig. 5) and from the Hambach Forest in Germany (Gaitzsch 1999, 135-39, figs 14-17), were Argonne ware and Mayen ware bowls.

The second form of containers was constructed from large tiles which formed the base and slabs of clay which formed the sides, and they were built into the structure of the furnace. These would have held a much larger quantity of glass than the coarseware pots. Examples found in the legionary fort at Bonn in lower Germany, were 0.9 metre long and 0.55-0.60 metre wide (Follman-Schultz 1991, 36, fig 6; 1992, 100, fig).

**Tools** Roman glassblowers are assumed to have used a range of metal and wooden tools somewhat similar to those used today, such as blowing irons, pontil irons, shears, pincers, moulds and other tools for manipulating the hot glass, but very few have been recognised. The wooden tools have generally disappeared without trace, and most of the metal tools are not sufficiently diagnostic to be identified unless they occur in association with other evidence for glassworking. The long iron blowpipe with an expanded terminal for gathering the glass from the crucible is the most recognisable tool associated with the glassblowing process. The scenes on the lamps and terracotta group described above show tools likely to be blowpipes, and a few examples of these and other tools have been recognised from glassworking sites. Several fragmentary iron tubes with expanded gathering terminals, a pair of iron pincers or shears and a solid iron rod, perhaps a pontil iron (Figure 4), were recovered in association with glass waste characteristic of blowing and fragments of fourth- to fifth-century vessels at Mérida (*Augusta Emerita*), western Spain (Price 1974, 80-84, figs 4-5; Lang and Price 1975), an iron tube found at Salona, Croatia was identified as a blowpipe (Auth 1975, 167), a piece of iron tube 0.832 m long from Sainte-Menehould, northern France is very probably a blow pipe (Foy and Sennequier 1989, 104 no 36, fig), and fragments of solid iron rods, perhaps pontil irons, and iron pincers or shears were found with a knife, a hammer, another iron tool and a terracotta mould in a third- or fourth-century context at Komarawo, Ukraine (Stern 1995, fig 8).

Single- and multi-piece moulds were used both to shape vessels during the blowing process and to decorate their surfaces. Some examples made in

terracotta, stone or metal have survived from the north west provinces and elsewhere in Roman world. Stone body and base moulds for square bottles are known at Augst (Rütti 1991, 162-64, fig 103, pl 218.05-06), Lyons (Foy and Sennequier 1989, 100-01), Saintes (Hochuli-Gysel 1993, 87, figs 5-7), and a half-mould of fired clay for forming a grape-flask is known from Macquenoise, Belgium (Chambon 1955, 3 and fig), and one-piece stone and metal moulds are also found occasionally (see Foy and Sennequier 1989, 102-03 nos 51 and 53 for examples from France).

**Waste glass** Additional evidence relating to glassworking tools such as the blowpipe, shears and pincers comes from various categories of glass production waste. The waste most diagnostic of glass blowing is the *moile*.<sup>10</sup> Two main forms are found, short cylindrical moiles from vessels with hot-finished rims which were separated at the time of blowing, and lid-shaped moiles from vessels with cold-finished rims which were separated after annealing. Moiles frequently have traces of iron scale or staining on the inside surface of the end attached to the blowpipe, and are

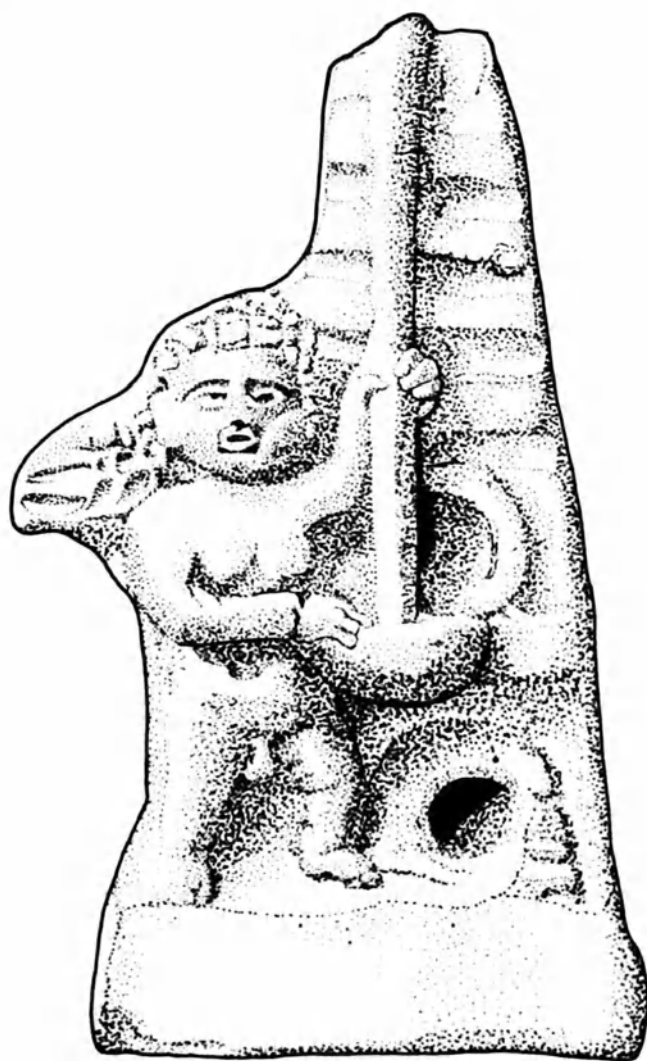


Figure 3. Winged figure holding blowing iron and crucible in front of glassworking furnace, Egyptian terracotta group (after Bird in Price 1988)



Figure 4. Iron glassworking tools from Mérida in western Spain (photo: J Price)

sometimes complete enough to provide information about the diameter of the gathering end of the pipe. Other categories of waste glass generated at production sites include trails, some twisted and showing the imprint of pincers, and drawn threads, and a range of drips and blobs, and pieces of glass detached from crucibles, as well as deposits of cullet.<sup>11</sup> Such material is found at glassworking sites in many parts of the Roman world, as in the *canabae* at Nijmegen (Isings 1980), Augst (Rütti 1991, 156-62, fig101), the Hambach Forest (Gaitzsch 1999, figs 6-7, 12, 15) and elsewhere.

### Evidence in Britain

No written evidence has direct relevance for glass production in Britain. The sole literary reference to glass in Britain occurs in Strabo (*Geography* iv, 6,3) in a passage which lists glass vessels among the items imported from Gaul in the reign of Augustus. Similarly, no iconographic or unequivocal epigraphic evidence has been recorded. It is conceivable that future excavations might produce a funerary monument of a glassworker, or a vessel with the name, initials or insignia of a town<sup>12</sup> or military unit, or a note about glass production written on a wooden tablet, but this has not happened yet!

The archaeological evidence in Britain indicates that glass production was usually sited within or close to military bases and towns. Glass workshops are often close to other industrial activities such as metalworking, boneworking or leatherworking, and in several cases there is a close association between glass and pottery production. With the exception of Coppergate in York, which is discussed below, all the glassworking finds in Britain (Figure 5) relate to

secondary production. Recent surveys have outlined the evidence for production in Britain (Price and Cool 1991; Price 1998) and this is summarised below.

Apart from a rectangular structure at Caistor by Norwich, the known furnaces are circular in plan with a single flue, and they are very small. The furnace structure dating from the middle of the second century or later which was found among pottery kilns at Mancetter in Warwickshire, was initially about 0.8m in internal diameter and was reduced in size thereafter by successive relinings (Figure 6). The furnace dating from the later third century in the corner of the Market Hall at Leicester was similar in size (Wacher 1978, pl. 30), and the one found among pottery kilns at Castor, Water Newton in Cambridgeshire, known only from a drawing (Figure 7), was probably comparable in dimensions (Artis 1828, pl XXV, 4-5). Very little is known about the furnaces in the industrial settlement at Wilderspool in Lancashire, but the published plans suggest they may have been similar in outline to the circular structures known elsewhere in Britain.

As in other provinces, the pots are open coarseware bowls. A third- or fourth-century Black-burnished flanged bowl was used as a crucible for glass in a workshop at Deansway, Worcester, and fragments of at least four coarseware bowls containing glass were found in late fourth-century levelling deposits in building 2, *insula* XXVII at Verulamium. Other fragmentary examples are known from Silchester, Castor, Water Newton, and Norton Folgate in London. The rim diameters of the largest of these vessels are around 0.27-0.30 metre and the base diameters about 0.18 metre but as their heights are not known their capacity is uncertain, although



Figure 5. Map: glassworking evidence in Britain

Boon (1974, 280-01) has calculated that the Silchester example may have been about 0.30 metre high, in which case it could have held 15 kilograms of glass. The only examples of tanks recorded in Britain have come from sites in London, where they are commoner than pots (Shepherd and Heyworth 1991, 14).

Glass waste is more commonly found. In southern Britain,

cylindrical and lid-shaped moiles have been noted in London, Colchester, Leicester, Mancetter, Wall in Staffordshire, Caerleon and Wroxeter, and pincer and twisted trails, drawn threads, rounded and misshapen lumps, glass from crucibles, wasters and cullet (Figure 8) at these sites and Castor, Water Newton, Wilderspool and Worcester. The quantities of this material are generally very small. However,





Figure 6. Glassworking furnace at Mancetter, Warwickshire (photo: K F Hartley)

an early second-century deposit of blowing and working waste and cullet weighing 50 kilos has been found in London, close to the fort at Cripplegate (John Shepherd *pers comm*), which indicates that glassworking may have been taking place on a large scale. By contrast with the evidence for reuse of glass at glassworking sites, there is little sign of the presence of lumps of raw glass, apart from one at Colchester (Cool and Price 1995, 209-10 no 2269, fig 12.1).

The surviving evidence for the size of the furnaces and the pots, and the quantity of waste glass found, gives an overall impression of small-scale glass production in Britain, though this may be rather misleading. The process of forming and finishing glass vessels and objects, unlike the firing of pottery vessels, takes place outside the furnace, so the size of the furnace and the pot only limits the amount of glass to be heated and worked at any one time, and the pots may well have been refilled many times before they were broken or replaced. In addition, it was common practice either to recycle all waste glass in subsequent melts in the same workshop or to collect this for remelting elsewhere, so the recovery of large quantities of cullet, as at

Cripplegate, is exceptional and may well indicate the deposition of material at the ending of an episode of production.

### Yorkshire and the North

In this region, as elsewhere in Britain, virtually all the archaeological evidence for glass production in the Roman period has been found in close association with military or urban settlements. The largest centre of population in the area was York. The legionary fortress housing in succession the



Figure 7. Glassworking furnace at Castor, Water Newton, Cambridgeshire (after Artis 1828)

Ninth *Hispana* and Sixth *Victrix* legions was sited there, and a city with chartered status was established on the opposite bank of the River Ouse.<sup>13</sup> It is therefore unsurprising that York has produced the widest range of evidence for glass production. Nonetheless, some relevant information has also come from other settlements, such as Castleford and Roxby, in Yorkshire, Binchester in County Durham, Carlisle in Cumbria, and from Newstead, Traprain Law, Camelon and Cramond in lowland Scotland (Figure 5).

The glass production evidence in York (see also Cool, this volume) comes from several find-spots. The Coppergate site, in the *canabae* outside the south-east corner of the legionary fortress, has produced the widest range of production evidence; this includes crucibles containing part-melted raw materials, crucibles with melted glass, a little evidence for glass blowing, and vessel fragments which may have been collected as cullet. Recent excavations in the grounds of the Royal York Hotel, outside the north corner of the *colonia*, have produced further evidence for glass melting in crucibles and a little evidence for blowing. There is also a very small amount of evidence for glassworking within the legionary fortress at Blake Street and the Minster site, where a trail with pincer marks and coloured glass cubes were found, and perhaps also in the *colonia* at Rougier Street, where a group of melted vessel fragments and small lumps may represent the collection of cullet.

Of these finds, the most extraordinary is the evidence for primary production at Coppergate. The Coppergate material was examined soon after excavation (Bayley 1987). When discovered, it was thought to belong to the Anglo-Scandinavian period, but was subsequently recognised

as Roman material redeposited in later contexts (Bayley 1987, 254). This assemblage of glass production evidence has been re-examined in detail recently (Jackson *et al* 1998; Cool *et al* 1999).<sup>14</sup> A total of 187 potsherds, weighing approximately 3 kilograms, came from buff-coloured and reddish pottery vessels dated to the late second or early third century. These had been used as crucibles and retained colourless or greenish glass on the inside or outside surface, ranging from a thin coating of glass on the upper parts to a thickness of 10 millimetres or more in the base. They represented a minimum of 36 vessels, mostly in Ebor Ware which was made in York (Monaghan 1997, 869-80, Swan, this volume). Twenty-four of the vessels were identified as bowls, and nine as either bowls or jars, with rim diameters between c 0.22 and c 0.38 metre, and the forms included one interpreted as a specialist vessel made for industrial use (see Cool, this volume, figure 4 for the range of vessel forms). It is noteworthy that the clay of the Ebor Ware vessels has good refractory properties and can be heated to at least 1150° centigrade without deforming.

By itself, this evidence does not indicate production from raw materials in York, although it points to glass melting taking place on a large scale. Cool *et al* (1999, 153) have calculated that the crucibles represented by the Coppergate fragments may have contained 0.32 cubic metre of glass. However, at least one of the crucibles had pieces of glass partially formed from raw materials (semi-reacted batch material) attached to the rim and outside surface, and similar pieces, which had presumably become detached, were found separately. The batch material consisted of partially fused quartz interspaced with glass or blocks of glass, with white frothy layers on top



Figure 8. Moiles and other glassworking waste from Wroxeter (Photo: Univ Leeds Photographic Service).



or inside the blocks. The batch material indicates that raw materials were used to make the glass, either in an unsuccessful attempt to make glass as a one-stage process or with the intention of fritting the raw materials as part of a two-stage process. The similarity of composition between the glass in the batch material and the glass in the crucibles, and the significant variations between both of these (slightly increased levels of iron, alumina and potassium) and the typical composition of Romano-British natron-based glass, has led Jackson *et al* (1998) and Cool *et al* (1999) to argue that the glass in the crucibles is also the result of primary manufacture of glass.

This material, which appears to be unparalleled in the Roman world, represents a very different kind of primary production from that recorded at Bet Eliezer and the other sites in the east Mediterranean region discussed earlier. It was small in scale, and involved the use of pottery vessels as crucibles to heat the raw materials. The semi-reacted batch had been heated to temperatures close to 1250°C, which may indicate that it represents a failed attempt to make glass by a one-stage rather than a two-stage process. Fritting would have required a much lower temperature (in the region of 600-750°C), and a pottery bowl would not perhaps have been a very practical form of container for burning off the impurities from the raw materials. In this respect, it is interesting that pottery vessels were used as crucibles for making the glass, rather than tanks. Tanks were shallow open containers, would have held larger quantities of glass and could presumably have been constructed from tiles made in the legionary kilns at York, so the preference for pots may be connected with the superior refractory properties of the Ebor Ware.

Bluish green glass, the commonest colour in the first to third centuries, was not present in the crucibles, and the distinctive composition of the glass contained in the crucibles was not otherwise recorded among the vessels or waste at Coppergate, which raises questions about the uses of this glass. It has been suggested that it may have been produced to make window panes, though no compositional links with window glass found in York have been noted. A small quantity of glassblowing debris was also found at Coppergate, consisting of 2 moiles and 3 other fragments, but this material was not related to the episode of glass making described above. In addition, a large quantity of vessel fragments which may have been collected for recycling was present at the site.

In 1999, excavations directed by Nick Pearson in the grounds of the Royal York Hotel produced pottery vessels with melted glass which were very similar to the Coppergate finds, as well as a little glass blowing waste (Hilary Cool *pers comm*; see also Cool, this volume).

Apart from these two sites, only a very small amount of evidence of glass working has been recognised. A single pincer trail was found at Blake Street (Cool *et al* 1995, 1592, 1661 no 6253, fig 752; see also Cool, this volume), but it is uncertain whether this represents the production of vessels or objects. Two small opaque blue cubes were also found at Blake Street (Cool *et al* 1995, 1592-93, 1661, nos 6251-52, fig 752), and two others, in opaque blue and opaque turquoise, at the Minster site (Price 1995, 353, 368 nos 93-95, fig 146). Similar cube-shaped lumps, which may be evidence

for some kind of glassworking or another industrial process, are discussed below in connection with material found at Castleford.

The practice of collecting broken glass for recycling is almost certain to have been in operation in York, and glass for recycling may also have been collected in settlements in the vicinity and then brought to the city. As already mentioned, many of the vessel glass fragments found at Coppergate may have been cullet, but deposits of this kind are generally difficult to identify in the absence of more diagnostic glassworking waste. A collection of at least 220 bluish green fragments, droplets and thin slivers of glass weighing 0.31 kilogram was found in one context at Rougier Street. Many of these were noticeably uniform in size - at least 90 measured approximately 40 x 25 millimetres - and in the degree of melting, and in the absence of black specks and charcoal embedded in the melted surfaces. They may perhaps have been cullet prepared for the production of objects, though this remains uncertain (see Cool, this volume).

Elsewhere in Yorkshire, two other settlements are known to have produced some evidence for glassworking. About fifty small cubes and melted lumps, one opaque yellow and the rest opaque blue, were found in the *vicus* at Castleford (Cool and Price 1998, 193-94). Small cube-shaped glass lumps, often known as *teserae*, have been found quite frequently on Romano-British sites, and they have frequently been assumed to come from late Roman mosaic pavements, such as one at Aldborough, North Yorkshire (Neal 1981, 38-39, fig 12). However, many of the sites producing glass cubes are early in date, and others have no evidence for the presence of mosaic pavements, so these objects may have quite different purposes. For example, small blue glass cubes were sometimes attached as decoration to pottery vessels. These have been found in Italy (Paul Roberts *pers comm*), but have not been noted in Britain. Alternatively, the cubes may be small quantities of raw glass for use in the production of glass objects. Guido (1978, 47, 100) suggested they were employed in the production of blue glass melon beads, though this may not be the case as most glass cubes are more or less opaque whereas the glass of melon beads is translucent.

Nearly all of the glass cubes at Castleford were found at one site (Site 1(74)) in the *vicus*, in mid second-century and later contexts. It is noteworthy that the same site also produced a very large proportion of the glass beads found at Castleford, and that most of the beads came from mid second-century contexts. Many of the bead forms are quite unusual, and the possibility of bead production at or near to the site in the middle of the second century has been discussed (Cool and Price 1998, 181-82). It is however, difficult to associate the glass cubes directly with any such bead production.

Another possibility is that the glass of the cubes might have been mixed with bluish green glass to produce streaky blue glass. Several categories of objects at Castleford were made in glass of this kind, including melon beads (nos 102-03), an annular bead (no 106) and a bangle (no 221), but evidence for association with the cubes is equivocal, as most of the objects either came from earlier phases of occupation than the glass cubes, or from the military settlement rather than the *vicus*. Finally, the glass lumps may have been intended for use as

enamel on copper alloy objects. There is good evidence for the presence of a workshop producing champlevé enamelled vessels at Castleford (Bayley and Budd 1998, 203-22; and Bayley, this volume) though it was a considerable distance from the *vicus*. It is arguable that some production of glass or enamelled objects took place in or close to the *vicus* in the mid second century but the nature of the activity is as yet unidentifiable.

Excavations at the late Iron Age-early Roman settlement at Roxby, on the North York Moors produced a small fragment of an oval-sectioned blue and green glass rod in House 2 (Inman *et al* 1985, 199-200, fig 5). This may be debris from some kind of glassworking, though what was being produced is not known. It is the only piece of evidence of the kind to be recorded from a round house in the region, and it is noteworthy that evidence for other craft activities, principally iron-working and jet-working, was also recorded in House 2 (see Wilson, this volume).

Lumps of dark green, dark blue and opaque white raw glass and glass waste were found at Bursea House during fieldwork and excavation in the parish of Holme on Spalding Moor in East Yorkshire in the past two decades. These were formerly thought to be Roman, but have now been shown to be not of Roman date; because of the presence of arsenic in the mix they are likely to come from post-medieval production (Henderson 1999; Halkon, this volume).

North of Yorkshire, the fort at Binchester in County Durham has produced twelve fragments of glassworking waste (Price and Worrell *forthcoming*). One greenish moile with iron-staining was noted, indicating that vessels were blown using an iron blowpipe, and the remainder were bluish green, greenish and colourless drips and trails with pincer marks. These finds came from late Roman and post Roman contexts, but the colour and quality of the glass of the moile suggests that the glass blowing occurred in the late third or fourth century. At Carlisle, a small fragment from the lower body and base of a pottery crucible containing bluish green glass was found at the Lanes, redeposited in a post-Roman context. Trails with pincer marks and rounded lumps were also recorded, providing further indications of some glass working activity (unpublished).

In lowland Scotland, two fragments of moiles have been noted from a pit in the annexe of the fort at Camelon, at least one of which may be lid-shaped. In addition, some vessel fragments were too distorted to have been used and some which did not appear to have been annealed. This material indicates an episode of glass blowing at the fort, probably during the late first-century occupation of the fort. It is noteworthy that the base of a furnace similar in plan to the Mancetter and Leicester glass furnaces, though larger in size, was also found in the annexe, but there is no certain association between the glassblowing waste and the furnace (Valerie Maxfield *pers comm*). There is a little evidence for glass melting at Cramond in Antonine and Severan contexts, where four groups of burnt clay fragments with deposits of blue/green vitreous material were found, but it is unclear whether this melting was intentional (Price *forthcoming*). Evidence for glass working has also been claimed at two other sites, the fort at Newstead and the hill top settlement at

Traprain Law, but the material is unpublished and no detailed information is currently available.

## Interpretation of the evidence

Examined critically, the glass working evidence from Yorkshire and the North described above represents one episode of primary production in the late second or early third century at Coppergate, York, but no identifiable products from this activity; and at least three episodes of production of blown vessels, at Coppergate, York where the date is not known, at Camelon probably in the late first century, and at Binchester, probably in the late third or fourth century. All the remaining evidence points only to the melting of glass and perhaps to the forming of objects.

This is, however, most unlikely to be an accurate reflection of the extent of glass production in the region. Both the military and the civil populations used glass extensively. Glass vessels are present in virtually all settlements both as tablewares for drinking and serving liquids and as containers for liquid and semi-liquid foodstuffs, cosmetics, medicines and other substances; a wide variety of glass objects and window panes are also found. Some of these were undoubtedly brought into the region from elsewhere, but some vessels, many of the objects and all of the window panes are likely to have been produced close to where they were used. It is thus likely that some form of glassworking took place at many of the settlements in the Roman North.

The army must have been involved in some of this production. Every auxiliary fort would have required window panes, at least for the high-status residential buildings and the bathhouse, and the glazing requirements of the legionary fortress would have been considerably greater. However, the extent to which the military personnel themselves were the glassworkers remains unclear. Little is recorded about soldiers engaged in glassworking, apart from a third-century tombstone at *Carnuntum* that commemorates a glazier in the Fourteenth *Gemina* legion (Bormann 1914, 336-40). The siting of glassworking activities in the *canabae* in York, in the fort annexes at Camelon and Newstead and within the fort at Binchester indicates close military control of the processes. The army in northern Britain is also likely to have been involved in the collection of broken bottles and other vessels as cullet for recycling in local workshops. The distribution patterns of the glass fragments in the Flavian legionary fortress at Inchtuthil suggest that the broken glass had been collected up before the abandonment of the site (Price 1985, 304), and the small size and fragmentary nature of the glass finds at the Minster site (Price 1995, 346) and at Coppergate points to the systematic collection of cullet.

Production in the towns presumably catered for the civil population and this may well have been organised independently of the military production. The civil settlements would have been a ready source of broken glass for recycling and there is some evidence that organised collection of this took place in towns in the region. For example, the differences in the size and number of fragments of broken vessels deposited at different periods at Blackfriars Street, Carlisle suggest that the organised collection of broken glass commenced after the end of the first century or



beginning of the second (Price 1990, 164).

Nothing is known in detail about the operation of the glass production sites of northern Britain, but it is possible that they operated intermittently rather than continuously, perhaps using the blowing and forming expertise of itinerant glassworkers to supply the local markets. In addition to the workshops known within or close to forts and towns, some glass production may perhaps have taken place in association with centres of pottery production, as has been noted elsewhere in Britain, although no evidence for this has yet been recognised.

There is very little information about the products of the workshops in the region. Window panes and many of the everyday tablewares and household vessels were probably produced locally; these probably did not travel long distances, either because they were unlikely to survive intact or because their value was less than the cost of transport, but it is generally not possible to recognise where they were produced. In the Roman world, the archaeological record of successful glassworking generally contains very few clues as to what was being produced, even if vestiges of the furnace and crucibles, or evidence for blowing and other production waste have survived. Many of the activities are likely to be completely invisible, because they did not involve the use of furnaces or crucibles.

The production of many categories of objects, such as beads, bangles, counters, finger rings and hairpins, belong to this 'invisible' category. Modern glassworkers have demonstrated that a wide range of beads can be produced by heating a lump of glass in a domestic fire or open hearth and manipulating it on a metal rod (Gam 1993, 261-267), and that seamless glass bangles and rings can be formed in a similar manner, using a second rod to widen the aperture symmetrically (Haevernich 1960, 23-28; Korfmann 1966). Similarly, plano-convex counters can be formed by dropping a small quantity of melted glass onto a flat surface, and hairpins by heating and manipulating glass rods. Therefore any discussion of individual centres of production for these and other objects is dependent on concentrations of finds and on the recognition of diagnostic manufacturing details. For example, the possibility of bead production in the *vicus* at Castleford discussed above was based on a significant concentration of unusual bead types. A similar case has been made for production of bangles with twisted cord decoration 'somewhere in the vicinity of York', based on the local concentration of finds (Price 1988b, 342-47), though this is unlikely to have been the only place of production, as similar bangles are found in southern Britain in the third quarter of the first century, and throughout the Roman North in late first- and early second-century contexts.

It is also possible that small and simple vessels could have been blown without using either a furnace or a crucible, either by heating a lump of glass in an open hearth, attaching it to the end of a blowing iron and blowing it to shape, or by fusing broken vessel fragments together to form a larger sheet of glass, attaching this to the end of a blowing iron and then re-heating and blowing it to form the vessel (George Scott *pers comm*). Each of these methods is technically possible using the sources of heat available in the Roman world,

although there is no certainty that either was in fact employed.

To sum up, the evidence for glass production in Yorkshire and northern Britain, most of which has come to light in the past two decades, is broadly comparable with that found elsewhere in the Roman world. The record is scattered and ephemeral, and many of the activities certain to have taken place in the region are simply not visible to the modern researcher. Nonetheless, some episodes of glass blowing and forming taking place at settlements in the region at various times from the later first to the fourth century have been identified, and more substantial information may well be discovered in the future.

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### Endnotes

1. Literary references to Roman glass production from the late first century BC onwards are numerous, and of varying value. The works of Strabo (*Geography*) and Pliny (*Natural History*) are well known, (see notes 4-6 and 11 below), and many other writers also make reference to aspects of glass production. A study of these has been made by Trowbridge (1930).
2. Epigraphic records provide a limited range of information about glassworkers. Funerary records indicate the place of death, and give the names and sometimes the place of origin, as on the early third-century tombstone of Julius Alexander at Lyons, who was of African origin and a citizen of Carthage (Foy and Sennequier 1989, 61-62 no 8). A few inscriptions on the body or base of mould-blown vessels or stamped into the handles of blown vessels also give both the name and place of origin, such as Aristas from Cyprus (Constable-Maxwell 1979, no 280), Artas and Philippos from Sidon (Fremersdorf 1938), and Sentia Secunda of Aquileia (Harden 1969, 49, 73, pl 4B) but these do not always indicate that the vessels were produced at the places named. It has been argued (Fremersdorf 1965/66, 29, pl 10.2) that the letters CCAA on the bases of bottles and flasks originate in the colonia at Köln (*Colonia Claudia Ara Agrippinensium*). Most frequently, only a personal name or an abbreviation is given, in which case any identification of a possible place or region of production is dependent on concentrations of finds, as is the case with bottles with abbreviations of Frontinus which are widely distributed in the middle and lower Rhineland, northern Gaul and Britain (Price 1978, 76, fig 61).
3. Very few representations of Roman glassworking have survived. Scenes on pottery lamps and a terracotta group (Abramic 1959; Baldoni 1987; Price 1988a) are discussed in this paper.
4. Although literary evidence indicates that some Mediterranean glass workers in the early Roman empire favoured particular sources of sand. Strabo (*Geography* 16, 758) recorded a source of sand between Ptolemais (Acre) and Tyre used by glassmakers at Sidon, and Pliny noted the glassmaking qualities of the sand from the mouth of the River Belus near Ptolemais (*Natural History*, 36, 190-92) and from the River Volturno found on the shore between Cuma and Literno in Campania (*Natural History*, 36, 194).
5. See Pliny, *Natural History*, 36, 192-94

6. This contrasts with Pliny's description of glassmaking. Writing in the third quarter of the first century AD, he indicated that glass in Campania was melted in a series of furnaces, being formed into lumps and then re-melted, which implies a fritting process (*Natural History* 36, 193-94).

Fritting is the preliminary heating of the raw materials to fuse them partially and to burn off impurities. The frit produced is then broken up and the best pieces are remelted to a much higher temperature to produce glass.

7. Other depictions have been claimed as representations of glass furnaces but the identifications are less secure. For example, a scene on a fragment from a fifth-century lamp found in Carthage was recently interpreted as a glass furnace and a glass blower (Caron and Lavoie 1997; Stern 1999, 445, fig 22). However, this interpretation does not take account of all the elements of the scene found on the complete lamps, which show that the structure and the human figure are sited in the top of a tree! (Donald Bailey *pers comm*; see also Bailey 1999)

8. Annealing is the process of reducing the temperature of glass vessels gradually to ensure uniform cooling of the surfaces to minimise the risk of them cracking or breaking; this may have taken place in a heated chamber or in a pit.

9. A pit of this kind was found in the late Antique glass workshop at Bet Sha'an (*Scythopolis*) in Israel (Yael Gorin-Rosen *pers comm*).

10. A moile is the glass between the end of the blowpipe and the top of the vessel which is left after the vessel has been blown and the rim finished off.

11. Cullet is broken vessel glass collected for remelting. The collection of broken glass is noted in Roman literature; Martial (*Epigrams* 1.41.1-5) and Statius (*Silvae* 1.6.70-74) both record this practice in Rome in the late first century AD, presumably for recycling (Leon 1941; Whitehouse 1999, 78).

12. It has been suggested (Price 1978, 70; Price and Cool 1991, 23) that the letters CCV found on the bases of some rectangular and square bottles in Britain (*RIB* II.2, no 2419.96-99) may indicate that they were produced in Colchester (*Colonia Claudia Victricensis*). However, this interpretation has been questioned, as the title *Claudia* is not directly attested in connection with Colchester (*RIB* II.2, 110).

13. Ottaway (1993, 64-66, fig 31) notes that Aurelius Victor, writing in the fourth century, described York as a *municipium* at the time of visit of Septimius Severus in AD 209, and it apparently became *colonia eburacensis* before AD 237 as it is thus described on the altar of M. Aurelius Lunaris.

14. I have also looked through the Coppergate material, but much of the information in this account is derived from the published accounts (Jackson *et al* 1998; Cool *et al* 1999).

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